

Appendix C

Field Performance Data for Compacted Clay Liners

by

David E. Daniel, Ph. D., P.E.
University of Illinois
Urbana, IL 61801

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Project Officer

Mr. David A. Carson
United States Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Cincinnati, OH 45268

Appendix C

Field Performance Data for Compacted Clay Liners

C-1 Introduction

The performance of compacted clay liners (CCLs) constructed from natural soil materials and soil-bentonite blends was discussed in Chapter 4. A number of graphs were presented correlating various parameters.

This appendix contains a summary of the data used in compiling the results presented in Chapter 4. The data are presented in this appendix in the form of tables of information. The intent is to provide sufficient information so that future researchers can add newly acquired data to the database and perform new analyses. Also, data on statistical variability of certain parameters was collected and is summarized in this appendix.

C-2 Data for Natural Soil Liner Materials

The data for natural soil liner materials are presented in four attached tables:

- Table C-1: Material properties
- Table C-2: Construction information
- Table C-3: Quality assurance information
- Table C-4: Hydraulic conductivity data

Each of the 89 sites is given a site number, which is shown in column 1 of all the tables. The symbols used are defined as follows:

Clay Fraction = percent on a dry weight basis finer than 2 μm
 D_F = maximum depth of penetration of wetting front into soil liner
 i = hydraulic gradient
 k = hydraulic conductivity
 L = thickness of soil liner
 LL = liquid limit of the soil
 MP = modified Proctor (ASTM D-1557)
 OWC = optimum water content
Percent Fines = percent on a dry weight basis passing the No. 200 sieve
Percent Gravel = percent on a dry weight basis retained on the No. 4 sieve
 PI = plasticity index of the soil
 P_o = percent of (w, γ_d) points lying on or above the line of optimums
 RC = relative compaction (dry unit weight of compacted soil divided by maximum dry unit weight from laboratory compaction test)
 RP = reduced Proctor (less than the compactive effort from SP)
 ΔS_i = degree of saturation of compacted soil minus degree of saturation on the line of optimum for the same dry unit weight
 SP = standard Proctor (ASTM D-698)

TSB = two-stage borehole test
w = water content as a percentage
w_{opt} = optimum water content
γ_d = dry unit weight
γ_{d,max} = maximum dry unit weight
σ' = effective stress in kPa
ψ_o = initial suction of soil liner

Some of the columns of data contain three data entries, one above the other, with the following meaning:

- Upper number is the number of data points
- Middle number is the average (geometric mean for hydraulic conductivity)
- Lower number is the standard deviation

C-3 Data for Soil-Bentonite Admixed Liners

Data for soil-bentonite admixed liners are presented in tables as follows:

- Table C-4: Material properties
- Table C-5: Construction information
- Table C-6: Quality assurance data
- Table C-7: Hydraulic conductivity data

The symbols are the same as those given in section C-2.

Table C-1. Material Properties for Natural Clay Liner Materials in Database.

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	w _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
1	SCA Wilsonville, IL Oct. 1992	Benson et al. 1992	-	-	-	-	-	10.2	20.1	SP
			24	10	4	65	37	9.0	21.3	MP
			-	-	-	-	-			
2	Confidential	Benson & Boutwell 1992	-	-	-	-	-	26.8	14.6	SP
			58	29	-	85	50			
			-	-	-	-	-			
3	Keele Valley Toronto, OT 1990	Lahti et al. 1987 Reades et al. 1990	-	-	-	-	-	12.3	19.0	SP
			25	10	2	85	22			
			-	-	-	-	-			
4	PAD B Livingston, LA 1987	Johnson et al. 1990	9	9	-	-	-	17.9	16.8	SP
			50	34	0	95	47			
			3	3	-	-	-			
5	Confidential	Benson & Boutwell 1992	-	-	-	-	-	14.3	18.6	MP
			43	26	3	87	32			
			-	-	-	-	-			
6	Confidential	Benson & Boutwell 1992	-	-	3	-	-	13.5	19.5	MP
			32	19		88	35			
			-	-	-	-	-			
7	Imperial, PA Dec. 1990	GeoSyntec Report	8	8	8	8	8	14.1	18.6	SP
			33	13	5	77	27			
			1	1	2	6	2			
8	Confidential	Benson & Boutwell 1992	-	-	-	-	-	14.5	18.8	MP
			35	22	1	75	45			
			-	-	-	-	-			

Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay (%<2 μm)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
9	Sauk City, WI 1988	Gordon et al. 1989	- 55 -	- 31 -	- 4 -	- - -	- 45 -	12.7	18.6	MP
10	Portage, WI 1988	Gordon et al. 1989	32 43 -	32 21 -	- 1 -	- - -	- 29 -	16.6	18.7	MP
11	Marathon, WI 1988	Gordon et al. 1989	- 57 -	- 30 -	- - -	- - -	- 39 -	21.7	17.3	MP
12	Marathon, WI 1988	Gordon et al. 1989	- 55 -	- 28 -	- - -	- - -	- 33 -	23.0	16.6	MP
13	Imperial, PA April 1991	GeoSyntec Report	8 37 1	8 15 1	8 2 1	8 78 5	8 37 4	18.0	17.0	SP
14	Test Fill 2 July 1988	Mundell & Boos 1990	3 40 8	3 20 3	6 0 -	6 70 8	6 25 11	16.2	16.7	SP
15	Confidential	Benson & Boutwell 1992	12 85 3	12 58 3	1 0 -	1 99 -	- 57 -	25.8	14.6	SP
16	Test Fill 1	Mundell & Boos 1990	24 41 9	24 22 6	20 0 -	20 77 -	20 38 8	15.8	17.0	SP
17	Livingston, LA Pad A Oct. 1988	Johnson et al. 1990	9 50 3	9 34 3	- 0 -	- 95 -	- 47 -	20.3	16.4	SP

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Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
18	Tangipahoa Landfill Amite, LA March 1992	Boutwell & McManis 1995	10	10	5	5	5	13.0	18.7	SP
			30	18	0	52	16			
			6	4	-	3	1			
19	Confidential	Benson & Boutwell 1992	12	12	12	12	12	10.5	20.1	MP
			32	14	1	85	44			
			3	2	1	3	4			
20	Confidential	Personal Files	-	-	-	-	-	18.5	17.2	SP
			49	23	1	94	43			
			-	-	-	-	-			
21	Confidential	Trast 1993	-	-	-	-	-	11.8	18.5	MP
			51	26	1	90	36	18.0	17.0	SP
			-	-	-	-	-	-	-	-
22	1993	Othman & Luettich 1994	-	-	-	-	-	20.5	16.3	SP
			63	42	-	96	-			
			-	-	-	-	-			
23	Green County, WI 1987	Krantz & Bailey 1990	20	20	-	-	-	20.0	16.5	SP
			39	18	-	73	30			
			4.2	3.8	-	-	-			
24	Confidential	Trast 1993	-	-	-	-	53	16.0	18.4	MP
			67	46	0	94	21.5	16.3	SP	
			-	-	-	-	-	-	-	
25	Confidential	Trast 1993	-	-	-	-	-	11.5	19.8	MP
			53	41	0	88	36	16.1	18.0	SP
			-	-	-	-	-	-	-	

Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
26	Confidential	Trast 1993	-	-	-	-	-	12.2	19.3	MP
			33	19	7	85	37	17.5	17.7	SP
			-	-	-	-	-	18.5	17.1	RP
27	Confidential	Trast 1993	-	-	-	-	-	12.5	19.4	MP
			31	18	8	74	26	16.5	17.8	SP
			-	-	-	-	-	18.5	17.2	RP
28	Confidential	Trast 1993	-	-	-	-	-	11.5	19.4	MP
			35	19	3	89	41	16.6	17.5	SP
			-	-	-	-	-	18.5	17.0	RP
29	ERC Facility Milan, MI 1993	Bergstrom et al. 1995	-	-	-	-	-	9.0	20.5	MP
			27	10	2	76	28	13.0	19.1	SP
			-	-	-	-	-	14.4	18.6	RP
30	Confidential	Personal Files	-	-	-	-	-	14.0	18.6	MP
			32	19	-	-	-	-	-	-
			-	-	-	-	-	-	-	-
31	Confidential	Personal Files	7	7	7	7	7	12.4	19.3	SP
			40	24	7	58	23	-	-	-
			1	1	4	3	1	-	-	-
32	Confidential	Personal Files	-	-	-	-	-	11.0	19.9	MP
			45	27	0	99	42	-	-	-
			-	-	-	-	-	-	-	-
33	Confidential	Personal Files	-	-	-	-	-	13.3	18.9	MP
			29	15	1	87	40	-	-	-
			-	-	-	-	-	-	-	-
34	Confidential	Personal Files	-	-	-	-	-	17.3	17.1	SP
			44	16	0	96	-	-	-	-
			-	-	-	-	-	-	-	-

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Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
35	Confidential	Personal Files	- 39 -	- 19 -	- 0 -	- 97 -	- - -	22.2	17.7	SP
36	Confidential	Personal Files	9 36 2.5	9 17 1.6	9 2 1.6	9 74 2.6	9 30 3.4	13.2	18.3	SP
37	Indianapolis, IN 1994	Personal Files	3 36 3	3 17 2	3 10 5	3 48 3	3 16 1	12.4	19.0	SP
38	ISGS Prototype Urbana, IL 1986	ISGS Report	- 21 -	- 7 -	- 9 -	- 60 -	- 26 - (4 μm)	10.3	20.4	SP
39	ISGS Field-Scale Urbana, IL April 1988	ISGS Report	- 21 -	- 7 -	- 9 -	- 60 -		10.3	20.4	SP
40	Confidential	Personal Files	15 101 5	15 71 5	- 0 -	- 98 -		31.6	13.4	SP
41	BP Chemicals SDRI 1 Port Lavaca, TX Nov. 1988	McBride-Ratcliff Report	- 47 -	- 30 -	- - -	- 66 -	- - -	19.5	16.3	SP
42	Celanese Bishop, TX July 1986	Personal Files	3 69 3.6	3 45 3.0	2 0 0	3 79 3.0	2 49 4.2	23.4	15.1	SP

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Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
43	GCWDA Test Fill A Texas City, TX Nov. 1988	Personal Files	119	119	-	119	-	22.4	15.4	SP
			62	42	-	86	-			
			4.1	4.3	-	6.2	-			
44	GCWDA Test Fill B Texas City, TX Nov. 1988	Personal Files	119	119	-	119	-	22.4	15.4	SP
			62	42	-	86	-			
			4.1	4.3	-	6.2	-			
45	Texas Eastman Longview, TX 1987	H.B. Zachry Co. Report	8	8	-	8	-	19.5	16.4	SP
			44	28	-	70	-			
			4.0	3.2	-	2.4	-			
46	Puckett Plant Ft. Stockton, TX April 1988	Personal Files	31	31	-	31	2	23.3	15.4	SP
			35	16	-	98	22			
			1.8	2.3	-	1.1	8.4			
47	Shell Deer Park, TX Dec. 1988	Personal Files	41	41	-	41	-	14.6	17.7	SP
			39	24.3	-	69.5	-			
			4.7	5.2	-	-	-			
48	Confidential	Personal Files	60	60	-	-	-	20.0	16.2	RP
			41	23	-	86	-	18.0	16.7	SP
			2.7	-	-	-	-	13.3	18.7	MP
49	Confidential	Personal Files	60	60	-	-	-	20.0	16.2	RP
			42	22	-	86	-	18.0	16.7	SP
			1.7	-	-	-	-	13.3	18.7	MP

Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	w _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
50	Confidential	Personal Files	88	88	-	-	-	20.0	16.2	RP
			43	24	-	86	-	18.0	16.7	SP
			3.4	-	-	-	-	13.3	18.7	MP
51	Confidential	Personal Files	62	62	-	-	-	20.0	16.2	RP
			40	22	-	86	-	18.0	16.7	SP
			1.9	-	-	-	-	13.3	18.7	MP
52	Emelle, AL Oct.1984	Golder Assoc. Report	2	2	3	3	3	19.9	16.5	SP
			37	18	10	73	38			
			1.4	2.8	8.9	15.1	9.0			
53	Confidential	Personal Files	8	8	8	-	8	19.9	16.4	SP
			54	31	0	-	40			
			2	3	0	-	3			
54	Quarantine Rd Landfill Baltimore, MD Jan. 1994	Personal Files	-	-	-	-	-	-	-	-
			-	-	-	-	-	-	-	-
			-	-	-	-	-	-	-	-
55	Savannah River Plant Panel A1 March 1988	Mueser-Rutledge Report	-	-	-	-	-	27.4	14.5	SP
			66	35	0	93	-			
			-	-	-	-	-			
56	Savannah River Plant Panel A2 March 1988	Mueser-Rutledge Report	-	-	-	-	-	27.4	14.5	SP
			66	35	0	93	-			
			-	-	-	-	-			
57	Savannah River Plant Panel B1 March 1988	Mueser-Rutledge Report	-	-	-	-	-	26.8	14.6	SP
			69	38	0	98	-			
			-	-	-	-	-			

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Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
58	Savannah River Plant Panel B2 March 1988	Mueser-Rutledge Report	- 69 -	- 38 -	- 0 -	- 98 -	- - -	26.8	14.6	SP
59	Savannah River Plant Panel B3 March 1988	Mueser-Rutledge Report	- 69 -	- 38 -	- 0 -	- 98 -	- - -	26.8	14.6	SP
60	Savannah River Plant Panel C1 March 1988	Mueser-Rutledge Report	- 68 -	- 35 -	- 0 -	- 95 -	- - -	26.6	14.6	SP
61	Savannah River Plant Panel C2 March 1988	Mueser-Rutledge Report	- 68 -	- 35 -	- 0 -	- 95 -	- - -	26.6	14.6	SP
62	Savannah River Plant Panel D1 March 1988	Mueser-Rutledge Report	- 51 -	- 20 -	- 0 -	- 73 -	- - -	20.2	15.9	SP
63	Savannah River Plant Panel D2 March 1988	Mueser-Rutledge Report	- 51 -	- 20 -	- 0 -	- 73 -	- - -	20.2	15.9	SP
64	BP Chemicals Port Lavaca, TX SDRI 2 Dec. 1988	McBride-Ratcliff Report	- 47 -	- 30 -	- - -	- 66 -	- - -	19.5	16.3	SP

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Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	w _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
65	BP Chemicals Port Lavaca, TX SDRI 3 Dec. 1988	McBride-Ratcliff Report	- 47 -	- 31 -	- - -	- 66 -	- - -	13.5	19.2	MP
66	Confidential	Personal Files	- 50 -	- 29 -	- - -	- 75 -	- - -	19.0	16.1	SP
67	Confidential	Personal Files	- 49 -	- 27 -	- - -	- 62 -	- - -	19.3	16.1	SP
68	Confidential	Personal Files	4 35 1	4 17 1	4 2 2	4 67 10	4 22 4	14.8 11.5	17.7 19.0	SP MP
69	Confidential	Personal Files	4 22 1	4 9 1	4 6 3	4 50 2	4 16 1	10.0 8.5	19.9 21.4	SP MP
70	Confidential	Personal Files	- 42 -	- 26 -	- 0 -	- 88 -	- 45 -	14.9	18.7	MP
71	Confidential	Personal Files	- 29 -	- 19 -	- 4 -	- 83 -	- 34 -	12.2	19.6	MP
72	SDDS Longtree LF Igloo, SD Feb. 1990	S. Dakota Disposal Systems Report	3 36 2.0	3 20 1.7	- 0 -	- 85 -	- 35 -	18.0	16.5	SP

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Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
73	Sea Drift, TX Sept. 1988	McClelland Engineers Report	4	4	-	-	-	21.0	15.5	-
			76	53	-	-	-			
			6.0	6.0	-	-	-			
74	Sea Drift, TX Sept. 1988	McClelland Engineers Report	4	4	-	-	-	18.0	16.9	-
			56	40	-	64	-			
			6.0	5.0	-	-	-			
75	McClellandtown, PA Sept. 1990	Cumberland Geot., Consultants Report	-	-	-	-	-	21.0	15.6	SP
			-	-	-	-	-			
			-	-	-	-	-			
76	Confidential	Personal Files	4	4	-	-	-	19.2	16.6	SP
			37	17	1	92	-			
			3.0	2.0	-	-	-			
77	Arnoni LF Pad 1 Pittsburgh, PA Feb. 1994	Personal Files	45	45	-	-	-	9.9	19.7	SP
			32	13	-	-	=19			
			0.8	0.9	-	-	-			
78	Arnoni LF Pad 2 Pittsburgh PA Feb. 1994	Personal Files	45	45	-	-	-	11.5	19.6	SP
			32	16	-	-	=25			
			1.6	1.3	-	-	-			
79	DuPont Pad 1 Victoria, TX Jan. 1989	Engineering Sciences Report	12	12	-	9	-	25.0	14.9	SP
			62	41	-	82	-			
			5.3	4.9	-	3.2	-			
80	DuPont Pad 2 Victoria, TX Jan 1989	Engineering Science Report	17	17	-	15	-	19.6	15.9	SP
			52	35	-	84	-			
			1.3	1.2	-	6.0	-			

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Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	w _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
81	GE Waterford, NY July 1989	Clough Harbor & Assoc. Report	- 47 -	- 22 -	- - -	- - -	- - -	25	15.3	SP
82	Findlay Township, PA Aug. 1988	Paul Rizzo & Assoc. Report	- - -	- - -	- - -	4 84 5.4	4 54 6.7	-	-	-
83	Findlay Township, PA Aug. 1988	Paul Rizzo & Assoc. Report	4 39 3.6	4 16 1.9	4 10 3.3	4 81 2.7	4 48 8.6	18.2	17.6	SP
84	Montezuma Hills, CA Pad A (Dark) Feb. 1991	IT Corp. Report	- - -	- - -	- - -	- - -	- - -	-	-	-
85	Montezuma Hills, CA Pad B (Light) Feb. 1991	IT Corp. Report	- - -	- - -	- - -	- - -	- - -	-	-	-
86	Fernald, OH Pad 1 (Ln. 1) Nov. 1996	GeoSyntec Report	- 43 -	- 24 -	- - -	- 84 -	- 37 -	17.7	17.1	SP
87	Fernald, OH Pad 1 (Ln. 2) Nov. 1996	GeoSyntec Report	- 43 -	- 24 -	- - -	- 84 -	- 37 -	17.7	17.1	SP

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Table C-1. Material Properties for Natural Clay Liner Materials in Database (Continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Clay Fraction (%<2 μm)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
88	Fernald, OH Pad 2 (Ln. 1) Nov. 1996	GeoSyntec Report	- 25 -	- 14 -	- - -	- 70 -	- 29 -	11.6	19.1	SP
89	Fernald, OH Pad 2 (Ln. 2) Nov. 1996	GeoSyntec Report	- 25 -	- 14 -	- - -	- 70 -	- 29 -	11.6	19.1	SP

Table C-2. Construction Information for Natural Clay Liner Materials in Database.

Site No.	Compaction Criteria	Compactor	Compactor Mass (kg)	Passes per Lift	Lift Thickness (mm)	Number of Lifts	Pad Size (m x m or m ²)
1	w > OWC RC > 90% MP	CAT 825	32,400	6	150	6	36 x 15
2	None	Bomag 210PD	-	6	150	5	32 x 14
3	w > OWC RC > 95% SP	Rex 370	30,000	4	150	8	30 x 30
4	w > OWC + 2, <+8 RC > 90% MP	CAT 815	19,800	-	150	4	15 x 30
5	w > OWC RC > 90% MP	Rex Trashmaster	36,000	6	150	10	Liner
6	w > OWC RC > 90% MP	CAT 825	32,400	5	150	6	29 x 12
7	w > OWC + 2 RC > 90% MP	CAT 825	32,400	4	150	8	15 x 24
8	w > OWC -2 to +4 RC > 90% MP	Dynapac CT25	12,600	4	150	6	24 x 18
9	w > OWC RC > 90% MP	-	-	-	150	10	Liner
10	w > OWC RC > 90% MP	-	-	-	150	10	Liner
11	w > OWC RC > 90% MP	-	-	-	150	10	Liner
12	w > OWC RC > 90% MP	-	-	-	150	10	Liner
13	w > OWC + 2, <+5 RC > 90% MP	CAT 825	32,400	4	150	8	15 x 24

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Table C-2. Construction Information for Natural Clay Liner Materials in Database (continued).

Site No.	Compaction Criteria	Compactor	Compactor Mass (kg)	Passes per Lift	Lift Thickness (mm)	Number of Lifts	Pad Size (m x m or m ²)
14	w > OWC + 2, <+5 RC > 90% MP	-	-	-	170	6	9 x 14
15	w > OWC RC > 100% SP	-	-	-	200	7	12 x 26
16	w > OWC + 2, <+5 RC > 90% MP	CAT 835	39,000	-	170	5	9 x 9
17	w > OWC + 2, <+6 RC > 90% SP	CAT 815	19,800	6	150	4	15 x 30
18	S _i > 78.5 RC > 90% MP	CAT D7G bulldozer	25,000	4	150	5	30 x 12
19	w > OWC RC > 90% MP	CAT 825	32,400	5	150	10	Liner
20	S _i > 82.0	CAT 825	32,400	8	150	6	45 x 20
21	w > OWC RC > 95% SP	CAT 825	32,400	6	150	6	58 x 26
22	S _i > 85.0	-	-	-	-	-	-
23	w > OWC RC > 90% MP	-	-	-	150	10	Liner
24	w > OWC RC > 90% MP	CAT 815A	18,900	8 - 12	150	5	31 x 15
25	w > OWC RC > 90% MP	CAT 815A	18,900	8 - 12	150	5	31 x 15
26	w > OWC RC > 90% MP	Dynapac CA25	18,900	4 - 6	150	6	27 x 17
27	w > OWC RC > 90% MP	Dynapac CA25	18,900	4 - 6	150	6	27 x 17

C-16

Table C-2. Construction Information for Natural Clay Liner Materials in Database (continued).

Site No.	Compaction Criteria	Compactor	Compactor Mass (kg)	Passes per Lift	Lift Thickness (mm)	Number of Lifts	Pad Size (m x m or m ²)
28	w > OWC RC > 90% MP	Dynapac CA25	18,900	4 - 6	150	6	27 x 17
29	w > OWC-2, +5 RC > 90% MP	CAT 825	32,400	6	170	9	32 x 16
30	RC > 90% MP	Rex Trashmaster	27,000	-	150	6	-
31	w > OWC RC > 95% SP	CAT S563	-	-	300	2	13 X 26
32	w > OWC, <+6 RC > 90% MP	CAT 825	32,400	-	150	8	15 x 40
33	w > OWC RC > 90% MP	CAT 815B	19,800	-	150	8	15 x 30
34	w > OWC RC > 95% SP	IR SPF-56 & CAT 815	19,800	4 (2 each)	150	3	-
35	w > OWC RC > 95% SP	CAT 824B	32,400	6	150	6	-
36	w > OWC, <+6 RC > 95% SP	CAT 815	17,100	8	60	6	15 x 30
37	w > OWC RC > 95% SP	FWD 741	-	4	60	5	-
38	w > OWC RC > 90% MP	Hyster C852A	-	12	150	6	3 x 9
39	w: 11 to 12% RC > 90% SP	CAT 815B	19,800	12	130	6	14.6 x 7.3
40	w > OWC, +5 RC > 92% SP	sheepsfoot	59 kg/lin. cm	-	150	6	8 x 26

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Table C-2. Construction Information for Natural Clay Liner Materials in Database (continued).

Site No.	Compaction Criteria	Compactor	Compactor Mass (kg)	Passes per Lifts	Lift Thickness (mm)	Number of Lifts	Pad Size (m x m or m ²)
41	RC > 95% SP	CAT 815	19,800	40	150	4	93
42	-	wedgefoot	-		150	4	30 x 15
43	w > OWC+1 RC > 95% SP	IR SPF-48	7,200	16	150	5	37 x 9
44	w > OWC+1 RC > 90% SP	IR SPF-48	7,200	8	150	5	37 x 9
45	w > OWC, <+2 RC > 95% SP	CAT 815 & Bomag BW213PD	19,800 14,000	4 2	150	4	288
46	w > OWC+1, <+3 RC > 95% SP	Dynapac CA25	10,900	8	200 - 250	5	15 x 30
47	w > OWC+1, <+5 RC > 90% SP	CAT 815B	19,800	6 - 10	85	10	46 x 24
48	w > OWC, <+3 RC > 95% SP	CAT 815B	19,800	5 - 8	150	4	46 x 15
49	w > OWC, <+3 RC > 95% SP	CAT 815B	19,800	3	150	4	46 x 15
50	w > OWC, <+3 RC > 95% SP	CAT 815B	19,800	3	150	4	46 x 15
51	w > OWC, <+3 RC > 95% SP	CAT 815B	19,800	4 - 5	150	4	46 x 15
52	w > OWC, <+3 RC > 95% SP	-	-	-	-	-	150
53	-	CAT 825C	-	4	-	4	-
54	-	-	-	-	150	4	-
55	-	CAT 815B	19,800	12	160	4	483

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Table C-2. Construction Information for Natural Clay Liner Materials in Database (continued).

Site No.	Compaction Criteria	Compactor	Compactor Mass (kg)	Passes per Lift	Lift Thickness (mm)	Number of Lifts	Pad Size (m x m or m ²)
56	-	Rex 3-50A & CAT 815B	19,800	6 (Lifts 1-3) 21 (Lift 4)	130	4	483
57	-	CAT 815B	19,800	6	140	4	483
58	-	CAT 815B	19,800	12	150	4	483
59	-	CAT 815B	19,800	12	170	4	483
60	-	CAT 815B	19,800	12	170	4	483
61	-	CAT 815B	19,800	12	190	4	483
62	-	CAT 815B	19,800	12	150	4	483
63	-	CAT 815B	19,800	12	230	4	483
64	RC > 95% SP	CAT 815	19,800	40	150	4	93
65	RC > 91% MP	CAT 815	19,800	80	150	4	186
66	w > OWC+1, <+5 RC > 95% SP	CAT 815	19,800	2	100	10	12 x 26
67	w > OWC+1, <+5 RC > 95% SP	CAT 815	19,800	2	100	11	12 x 26
68	w > OWC+1, <+5 RC > 95% SP	CAT 815B	19,800	6	150	4	15 x 36
69	w > OWC+1, <+5 RC > 95% SP	CAT 815B	19,800	6	150	4	15 x 36
70	w > OWC-2, <+4 RC > 90% MP	-	-	7 to 10	150	6	24 x 18
71	w > OWC-2, <+4 RC > 90% MP	-	-	7 to 10	150	6	24 x 18
72	w > OWC, <+6 RC > 95% SP	CAT 825C	32,400	8	150	4	18 x 36

C-19

Table C-2. Construction Information for Natural Clay Liner Materials in Database (continued).

Site No.	Compaction Criteria	Compactor	Compactor Mass (kg)	Passes per Lift	Lift Thickness (mm)	Number of Lifts	Pad Size (m x m or m ²)
73	w > OWC, <SL RC > 95% SP	CAT 815B	19,800	22	1 @ 200 6 @ 100	7	12 x 23
74	w > OWC, <SL RC > 95% SP	CAT 815B	19,800	22	1 @ 200 6 @ 100	7	12 x 23
75	w > OWC+3, <+6 RC > 95% SP	CAT 815B	19,800	-	1 @ 200 3 @ 150	4	15 x 30
76	w > OWC+3, <+5 RC > 95% SP	CAT 815B	19,800	6	150	4	18 x 30
77	w > OWC+0.4 RC > 98% SP	IR SD-100D	10,200	10	100	9	15 x 30
78	w > OWC+1.5 RC > 94% SP	IR SD-100D	10,200	4	100	9	15 x 30
79	w > OWC RC > 95% SP	CAT 815B	19,800	8	150	8	465
80	w > OWC RC > 95% SP	CAT 815B	19,800	8	150	8	465
81	w > OWC+4	Dresser VOS PD84A	16,200	4	150	4	465
82	RC > 96% SP	CAT 825 & Vib. Smooth Drum	32,400 -	6 2	150	4	223
83	RC > 96% SP	CAT 825 & Vib. Smooth Drum	32,400 -	6 2	150	4	223
85	RC > 90% MP	CAT 815B	19,800	-	1 @ 300 3 @ 200	20 x 24	-

C-20

Table C-2. Construction Information for Natural Clay Liner Materials in Database (continued).

Site No.	Compaction Criteria	Compactor	Compactor Mass (kg)	Passes per Lift	Lift Thickness (mm)	Number of Lifts	Pad Size (m x m or m ²)
85	RC > 90% MP	CAT 815B	19,800	-	1 @ 300 3 @ 200	20 x 24	-
86	W > OWC, <+4; RC > 95% SP	CAT 815	19,800	4	150	6	13 x 15
87	W > OWC, <+4; RC > 95% SP	CAT 815	19,800	7	150	6	13 x 15
88	W > OWC, <+4; RC > 95% SP	CAT 815	19,800	4	150	6	13 x 15
89	W > OWC, <+4; RC > 95% SP	CAT 815	19,800	6	150	6	13 x 15

Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database.

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
1	34 10.3 0.8	34 19.8 0.036	44	- 2.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
2	57 26.6 2.2	57 14.4 4.0	28	-4.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
3	- 13.8 -	- 19.4 -	98	+17.7	None	Verify $k \leq 1 \times 10^{-8}$ cm/s	
4	4 21.3 0.5	4 16.0 0.17	80	+3.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s ; show KF = KL using standard construction methods	Compacted slightly wet of modified Proctor optimum and wet of line of optimums
5	21 17.3 2.2	21 17.3 0.51	95	-3.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
6	32 13.8 0.9	37 19.0 0.31	32	-8.2	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Met CQA Spec, but dry of line of optimums
7	33 17.2 1.5	33 17.7 0.47	88	+1.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
8	17 15.3 1.2	17 17.7 0.9	8	-12.6	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
9	85 19.6 1.9	85 17.0 0.31	90	+5.8	None	Monitor liner performance and Verify $k \leq 1 \times 10^{-7}$ cm/s	

C-22

Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
10	93 17.8 1.5	93 16.9 0.34	50	+3.5	None	Monitor liner performance and verify $k \leq 1 \times 10^{-7}$ cm/s	
11	91 25.4 3.2	9100 16.0 0.66	75	-7.4	None	Monitor liner performance and verify $k \leq 1 \times 10^{-7}$ cm/s	
12	289 26.0 2.3	289 16.1 0.50	78	+4.6	None	Monitor liner performance and verify $k \leq 1 \times 10^{-7}$ cm/s	
13	34 20.7 0.6	34 16.7 0.24	100	+9.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
14	18 17.0 0.9	18 16.8 0.16	78	+4.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
15	48 30.8 0.5	48 14.1 0.27	48 98 -	48 +8.0 0.03	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
16	11 19.8 1.2	11 16.1 0.22	91	+6.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
17	16 23.3 1.2	16 15.7 0.44	100	+3.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s; show KF = KL using standard construction methods	
18	20 16.6 0.9	20 17.35 0.25	85	+4.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	

C-23

Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
19	584 13.6 0.72	584 19.0 0.19	81	+3.8	None	Monitor liner performance and verify $k \leq 1 \times 10^{-7}$ cm/s	
20	37 17.6 0.52	37 16.9 0.33	8	-6.2	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Compacted dry of line of optimums using acceptable zone approach
21	18 19.5 0.3	18 16.9 0.15	80	+4.3	None	Verify Suitability of Silty Material for $k \leq 1 \times 10^{-7}$ cm/s	
22	-	-	-	-3.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Spec. required that $S_o \geq 90\%$
23	60 22.0 2.8	60 16.4 0.57	89	+7.4	None	Monitor liner performance and verify $k \leq 1 \times 10^{-7}$ cm/s	
24	19 23.6 1.1	19 15.8 0.32	81	+0.4	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
25	18 18.9 0.31	18 16.9 0.42	71	-0.5	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
26	53 15.5 -	53 17.6 -	17	-8.8	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	In spec, but dry of line of optimums
27	36 13.5 -	36 18.0 -	6	-10.4	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	In spec, but dry of line of optimums

C-24

Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
28	54 16.2 -	54 17.7 -	57	-0.3	None	Verify $K < 1 \times 10^{-7}$ cm/s	In spec, but straddles line of optimums
29	92 13.9 0.71	92 18.8 0.28	84	+1.0	None	Verify $K < 1 \times 10^{-7}$ cm/s	
30	- 16.2 -	- 18.6 -	65	-2.3	None	Verify $K < 1 \times 10^{-7}$ cm/s	
31	- 13.1 -	- 19.1 -	75	-1.5	None	Verify $K < 1 \times 10^{-7}$ cm/s	
32	- 13.9 -	- 19.2 -	92	+7.5	None	Verify $K < 1 \times 10^{-7}$ cm/s	
33	- 13.4 -	- 18.7 -	80	+0.7	None	Verify $K < 1 \times 10^{-7}$ cm/s	
34	- 17.8 -	- 17.1 -	45	+2.5	None	Verify $K < 1 \times 10^{-7}$ cm/s	
35	- 20.7 -	- 16.8 -	78	+2.8	None	Verify $K < 1 \times 10^{-7}$ cm/s	
36	- 15.5 -	- 17.6 -	77	+3.4	None	Verify $K < 1 \times 10^{-7}$ cm/s	Constructed with mine spoil

C-25

Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
37	- 14.1 -	- 18.2 -	45	-1.2	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Disturbance in tube by gravel
38	24 11.5 3.6	24 20.4 0.77	Raw Data NA	+10.2	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
39	57 11.6 1.1	57 17.9 0.82	10	-19	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
40	40 35.5 0.5	40 12.8 0.17	100	+0.03	Desiccation (Hot HDPE)	Verify $k \leq 1 \times 10^{-7}$ cm/s	
41	13 21.9 0.88	13 16.0 0.22	92	+5.6	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
42	26 25.0 1.5	26 15.1 0.36	81	+5.5	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
43	49 23.4 1.12	49 15.4 0.28	63	+3.9	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	East Side = A, West = B; used <u>light</u> roller
44	49 24.2 1.5	49 15.0 0.40	47	+1.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
45	31 19.8 1.03	31 103.8 2.61	71	+0.4	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Nothing unusual

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Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
46	32 27.3 3.4	32 15.4 0.22	100	+8.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Cell 1E had SDRI, $G_s = 2.67$ measured
47	51 16.5 1.25	51 17.7 0.50	100	+9.9	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
48	160 17.8 0.40	160 17.0 1.1	75	1.1	potentially desiccation or freeze-thaw damage	Verify $k \leq 1 \times 10^{-7}$ cm/s	Pads at Sites 48-51 were constructed with same material by 4 different contractors. Objective in each case to obtain $KF \leq 10^{-7}$ cm/s, with low bid/low K contractor winning job.
49	152 18.9 1.05	152 16.7 0.25	86	0.3	potentially desiccation or freeze-thaw damage	Verify $k \leq 1 \times 10^{-7}$ cm/s	
50	216 18.6 1.16	216 16.9 0.37	84	1.3	potentially desiccation or freeze-thaw damage	Verify $k \leq 1 \times 10^{-7}$ cm/s	
51	152 17.8 1.10	152 17.0 0.40	73	-0.7	potentially desiccation or freeze-thaw damage	Verify $k \leq 1 \times 10^{-7}$ cm/s	
52	9 21.2 1.08	9 16.1 0.32	67	+1.5	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
53	32 21.6 2.2	32 15.5 0.36	32 71	32 +0.02 0.04	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	

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Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
54	- - -	- - -	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	SDRI Test on Liner
55	- 27.0 0.7	- 15.0 0.22	100*	+5.9	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s; $w \approx w_{opt}$	$k > 1 \times 10^{-7}$ because soil wasn't wet enough
56	- 30.6 0.7	- 14.2 0.17	100*	+6.6	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s; $w \approx w_{opt} + 3\%$	Wetting soil up to opt. +3% lowered k (compared to site 55)
57	- 29.6 1.1	- 14.0 0.30	100*	+0.5	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s	
58	- 30.7 1.3	- 14.3 0.22	100*	+8.6	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s	
59	- 29.4 1.3	- 14.4 0.31	100*	+6.3	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s	
60	- 26.8 0.8	- 15.1 0.20	100*	+8.4	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s; $w \approx w_{opt}$	
61	- 29.8 0.4	- 14.4 0.14	100*	+7.6	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s; $w \approx w_{opt} + 3\%$	

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Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
62	- 24.6 0.6	- 15.4 0.17	100*	+10.9	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s	
63	- 22.7 0.5	- 15.4 0.16	100*	+3.2	None	Verify suitability of soil for $k \leq 1 \times 10^{-7}$ cm/s	
64	8 21.6 0.32	8 16.0 0.22	88	+4.3	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
65	23 17.2 1.07	23 17.4 0.31	0	-6.1	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
66	39 21.7 1.3	59 17.2 0.52	95	+8.6	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
67	59 21.41.2	59 17.2 0.52	98	+8.1	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
68	13 17.6 1.0	13 18.0 0.38	100	+6.4	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
69	8 11.5 0.6	8 19.4 1.6	75	+8.0	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
70	- 20.6 -	- 16.1 -	60	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	

C-29

Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
71	- 14.3 -	- 18.0 -	64	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
72	6 23.7 1.0	6 15.5 0.2	100	11.3	freeze-thaw, but upper lift re-worked before SDR1	Verify $k \leq 1 \times 10^{-7}$ cm/s	
73	36 25.2 1.2	36 14.8 0.86	97	5	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	On site clay
74	30 19.6 1.6	30 16.1 0.02	47	-3.7	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Off site clay
75	7 25.4 2.0	7 15.2 0.7	100	11.1	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
76	76 21.8 0.4	76 15.9 0.3	86	1.1	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
77	111 11.0 0.6	111 19.2 0.6	37	1.1	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
78	109 12.4 1.5	109 18.8 0.5	2	-7.2	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	

C-30

Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
79	39 28.2 3.1	37 16.2 0.49	-	12.6	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
80	37 23.1 2.2	39 14.9 0.46	-	11.7	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
81	8 28.0 2.5	8 14.2 0.20	-	2.7	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
82	14 17.8 2.0	14 17.1 0.44	-	2.4	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
83	16 19.3 1.5	16 17.3 0.53	-	12	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
84	-	-	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Dark clay
85	-	-	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	Light clay
86	18 20.5 2.3	18 16.6 0.68	100	5.5	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
87	19 20.4 2.2	19 16.6 0.61	95	4.1	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	

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Table C-3. Quality Control/Quality Assurance Data for Natural Clay Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P_o	ΔS_i	Distress	Purpose	Remarks
88	24	24	100	11.7	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
	13.2	19.2					
	0.8	0.35					
89	29	29	100	10.8	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
	13.2	19.1					
	1.1	0.45					

Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database.

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ ₀ (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
1	4 3.2 x 10-8 0.32	D 5084 69 10	2.8 x 10-7	1.44	-	-	-	2.6 x 10-7	1	60
2	2 3.6 x 10-9 -	- - -	1.5 x 10-7	1.82	-	-	-	-	1	70
3	109 8.0 x 10-9	Flexible-Wall 165 20	-	-	9 x 10-9	15 x 15	-	-	-	-
4	4 5.0 x 10-9 0.34	9100 - -	1.1 x 10-7	2.33	-	-	-	-	0.3	-
5	3 8.7 x 10-9 0.21	D 5084 69 10	9 x 10-9	1.49	-	-	-	4 x 10-8	0.6	80
6	4 2.4 x 10-8 0.46	Flexible-Wall - -	2.7 x 10-7	2.33	-	-	-	-	0.7	70
7	8 8.4 x 10-8 0.35	D 5084 - -	5.8 x 10-8	2.33	-	-	5 4.3 x 10-8 0.12	-	-	-
8	5 9.0 x 10-9 0.58	D 5084 - -	1.2 x 10-7	2.33	-	-	-	-	-	-

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database (continued).

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _{F/L}	Ψ _o (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
9	- 1.0 x 10 ⁻⁸ -	- - -	-	-	7 x 10 ⁻⁹	-	-	-	-	-
10	- 8.0 x 10 ⁻⁹ -	- - -	-	-	3 x 10 ⁻⁸	-	-	-	-	-
11	- 2.0 x 10 ⁻⁹ -	- - -	-	-	3 x 10 ⁻⁹	-	-	-	-	-
12	- 3.0 x 10 ⁻⁹ -	- - -	-	-	2 x 10 ⁻⁹	-	-	-	-	-
13	8 1.3 x 10 ⁻⁸ 0.18	D 5084 69 -	1.3 x 10 ⁻⁸	2.33	-	-	5 1.4 x 10 ⁻⁸ 0.16	-	0.1	-
14	4 4.8 x 10 ⁻⁸ 0.29	- - -	2.0 x 10 ⁻⁸	2.33	-	-	-	-	0.2	-
15	10 4.4 x 10 ⁻⁹ 0.48	9100 - -	3.3 x 10 ⁻⁹	2.33	-	-	4 1.6 x 10 ⁻⁸ 0.21	-	0.7	-
16	7 3.7 x 10 ⁻⁸ 0.48	D 5084 - -	3.0 x 10 ⁻⁸	2.33	-	-	-	-	0.1	-

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database (continued).

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
	k	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
17	7 3 x 10 ⁻⁹ 0.19	9100 34 -			6 6 x 10 ⁻⁹ 0.25	0.37	6 5 x 10 ⁻⁹ 0.23	-	1.0	-
18	5 1.5 x 10 ⁻⁸ 0.12	D 5084 34 -	9.8 x 10 ⁻⁹	2.33	-	-	8 9.2 x 10 ⁻⁹ 0.26	4 1.4x10 ⁻⁸ 0.34	-	-
19	8 1.9 x 10 ⁻⁸ 0.46	- - -	-	-	4.4 x 10 ⁻⁸	8 x 8	-	-	-	-
20	9 3.0 x 10 ⁻⁹ 0.63	D 5084 35 -	8 x 10 ⁻⁷	2.33	-	-	-	-	1	30
21	2 3.1 x 10 ⁻⁷ -	D 5084 69 10	2.5 x 10 ⁻⁷	2.33	-	-	-	2 2.2 x 10 ⁻⁷ -	1	-
22	- 2.4 x 10 ⁻⁸ -	- - -	2 x 10 ⁻⁸	2.33	-	-	-	-	-	-
23	6 1.5 x 10 ⁻⁸ 0.45	- - -	-	-	1.4 x 10 ⁻⁸	-	-	-	-	-
24	2 9 x 10 ⁻⁹ -	D 5084 69 10	1.5 x 10 ⁻⁸	2.33	-	-	-	1.1 x 10 ⁻⁸	1	45

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database (continued).

Site	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
No.	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
25	2 2.3 x 10 ⁻⁹ -	D 5084 69 10	8 x 10 ⁻⁹	2.33	-	-	-	6 x 10 ⁻⁹	1	35
26	2 2.9 x 10 ⁻⁹ -	D 5084 69 10	2.0 x 10 ⁻⁷	2.33	-	-	-	1.8 x 10 ⁻⁷	1	-
27	2 3.0 x 10 ⁻⁸ -	D 5084 69 10	1.8 x 10 ⁻⁷	2.33	-	-	-	1.5 x 10 ⁻⁷	1	-
28	2 1.9 x 10 ⁻⁸ -	D 5084 69 10	9 x 10 ⁻⁸	2.33	-	-	-	1.7 x 10 ⁻⁷	1	-
29	2 2.2 x 10 ⁻⁸ -	D 5084 69 10	3 1.7 x 10 ⁻⁸ -	1.85	-	-	-	2 1.7 x 10 ⁻⁸ -	1	-
30	- 3.0 x 10 ⁻⁸ -	Flexible-Wall - 22	1.1 x 10 ⁻⁷	2.33	-	-	-	-	> 0.7	-
31	7 1.6 x 10 ⁻⁸ 0.26	D 5084 - -	6.0 x 10 ⁻⁸	2.33	-	-	6 4.7 x 10 ⁻⁸ 0.034	--	1	32
32	2 3.0 x 10 ⁻⁸ -	Flexible-Wall - -	3.9 x 10 ⁻⁸	2.33	-	-	-	-	1	0

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database (continued).

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	K (cm/s)	k (cm/s)		
33	2 1.3 x 10 ⁻⁸ -	- - -	3.9 x 10 ⁻⁸	2.33	-	-	-	-	1	0
34	6 1.5 x 10 ⁻⁸ 0.62	D 5084 69 10	4 x 10 ⁻⁷	2.33	-	-	-	3 3.5 x 10 ⁻⁷ 0.23	1	-
35	2 3.0 x 10 ⁻⁸ -	- - -	3.7 x 10 ⁻⁸	2.33	-	-	-	-	>0.7	-
36	6 9.1 x 10 ⁻⁹ 0.58	D 5084 21 20	3.0 x 10 ⁻⁸	2.33	-	-	-	-	>0.7	25
37	- 4.9 x 10 ⁻⁸ -	Flexible-Wall - -	1.3 x 10 ⁻⁸	2.33	-	-	-	-	0.5	--
38	- - -	- - -	<3.6x10 ⁻⁸	0.16	-	-	-	-	0.1	-
39	6 2.6 x 10 ⁻⁸ 0.14	D 5084 14 10	2.6 x 10 ⁻⁹ 4.3 x 10 ⁻⁹	0.08 m ² 1.76 m ²	No Flow	-	-	-	0.5	-
40	7 3.5 x 10 ⁻⁹ 0.35	D 5084 34 -	2.2 x 10 ⁻⁸		-	-	7 1.6 x 10 ⁻⁸ 0.33	-	0.8	-
41	5.5 x 10 ⁻⁹	-	1.0 x 10 ⁻⁷	2.33	-	-	-	4.1x10 ⁻⁹	0.24	-

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database (continued).

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
42	-	-	8 x 10-8	2.33	-	-	-	-	-	-
43	3 2.4 x 10-9 0.12	Const. Head - -	7 x 10-8	2.33	-	-	-	-	-	-
44	3 2.4 x 10-9 0.13	Const. Head - -	2 x 10-7	2.33	-	-	-	-	-	-
45	12 5.8 x 10-9 0.63	- - -	3.7 x 10-8	2.33	-	-	-	-	0.5	-
46	9 1.5 x 10-8 0.12	- - -	2 x 10-8	2.33	-	-	-	-	-	-
47	-	-	5x10-8	2.33	-	-	-	-	0.5	20
48	3 1.1 x 10-8 0.21	D 5084 69 10	4 x 10-8	2.33	-	-	5 2.1x10-8 0.57	4.8x10-8	1	32
49	4 5.1 x 10-8 0.67	D 5084 69 10	5.0 x 10-8	2.33	-	-	5 3.2 x 10-7 1.07	7.7x10-8	1	35
50	3 7.4 x 10-8 0.31	D 5084 69 10	2.6 x 10-7	2.33	-	-	5 7.5 x 10-8 1.20	3.1x10-6	1	34
51	3 4.1 x 10-8 0.15	D 5084 69 10	3.0 x 10-7	2.33	-	-	5 1.1 x 10-7 1.08	5.3x10-7	1	22

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database (continued).

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ ₀ (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
52	- - -	- - -	2 1.1 x 10 ⁻⁷ 0.10	7.20	-	-	-	-	-	2
53	4 1.7 x 10 ⁻⁸ 0.21	D 5084 - -	2.2 x 10 ⁻⁸	2.33	-	-	5 1.2 x 10 ⁻⁸ 0.35	-	0.2	-
54	-	-	7 x 10 ⁻⁸	2.33	-	-	-	-	1	70
55	- 8.1 x 10 ⁻⁸ -	- - -	1.3 x 10 ⁻⁷	2.33	-	-	-	-	0.67	-
56	- 2.8 x 10 ⁻⁸ -	- - -	2.4 x 10 ⁻⁸	2.33	-	-	-	-	0.63	-
57	- 3.4 x 10 ⁻⁸ -	- - -	5.6 x 10 ⁻⁸	2.33	-	-	-	-	0.71	-
58	- 2.5 x 10 ⁻⁸ -	- - -	5.0 x 10 ⁻⁸	2.33	-	-	-	-	0.71	-
59	- 2.7 x 10 ⁻⁸ -	- - -	9.4 x 10 ⁻⁸	2.33	-	-	-	-	0.54	-
60	- 3.4 x 10 ⁻⁸ -	- - -	1.2 x 10 ⁻⁷	2.33	-	-	-	-	0.63	-

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database (continued).

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	K (cm/s)		
61	- 4.3 x 10 ⁻⁸ -	- - -	3.7 x 10 ⁻⁸	2.33	-	-	-	-	0.63	-
62	- 1.6 x 10 ⁻⁷ -	- - -	3.1 x 10 ⁻⁷	2.33	-	-	-	-	0.75	-
63	- 1.7 x 10 ⁻⁷ -	- - -	3.9 x 10 ⁻⁷	2.33	-	-	-	-	0.54	-
64	- 5.5 x 10 ⁻⁹ -	- - -	2.3 x 10 ⁻⁷	2.33	-	-	-	4.1 x 10 ⁻⁹	0.25	-
65	-	-	1.8 x 10 ⁻⁷	2.33	-	-	-	-	0.80	-
66	3 3.7 x 10 ⁻⁸ 0.31	D 5084 - -	1.2 x 10 ⁻⁸	2.33	-	-	5 1.1 x 10 ⁻⁸ 0.26	-	> 0.5	26
67	3 3.0 x 10 ⁻⁸ 0.30	D 5084 - -	8.3 x 10 ⁻⁸	2.33	-	-	5 8.5 x 10 ⁻⁸ 0.21	-	> 0.5	34
68	4 7.8 x 10 ⁻⁹ 0.14	D 5084 22 34	2 2.3 x 10 ⁻⁸ 0.017	2.33	-	-	5 2.6 x 10 ⁻⁸ 0.11	-	> 0.7	60
69	4 2.1 x 10 ⁻⁸ 0.33	D 5084 22 34	2 1.3 x 10 ⁻⁸ 0.002	2.33	-	-	5 5.6 x 10 ⁻⁸ 0.12	-	> 0.7	46

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Database (continued).

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
70	- 2 x 10 ⁻⁸ -	Flexible-Wall - -	4 x 10 ⁻⁸	2.33	-	-	-	-	-	-
71	- 2 x 10 ⁻⁸ -	Flexible-Wall - -	8.3 x 10 ⁻⁸	2.33	-	-	-	-	-	-
72	2 1.4 x 10 ⁻⁸ 0.06	- 52 -	2.0 x 10 ⁻⁸	2.33	-	-	-	-	0.5	-
73	-	-	8 x 10 ⁻⁸	2.33	-	-	-	-	0.6	-
74	-	-	1 x 10 ⁻⁹	2.33	-	-	-	-	0.5	-
75	-	-	5 x 10 ⁻⁸	2.33	-	-	-	-	1	-
76	4 4.7 x 10 ⁻⁸ 1.1	- 52 -	3 x 10 ⁻⁸	2.33	-	-	-	-	1	-
77	-	-	2 x 10 ⁻⁸	2.33	-	-	-	-	0.5	-
78	-	-	2 x 10 ⁻⁸	2.33	-	-	-	-	0.5	-
79	5 3.3 x 10 ⁻⁹ 0.22	- - -	2 4.5 x 10 ⁻⁸ -	2.33	-	-	-	-	-	-
80	3 1.8 x 10 ⁻⁹ 0.15	- - -	2 4.0 x 10 ⁻⁸ -	2.33	-	-	-	-	0.4	-
81	2 4.2 x 10 ⁻⁸ 0.27	- - -	1.5 x 10 ⁻⁷	2.33	-	-	-	-	0.8	-

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Table C-4. Hydraulic Conductivity for Natural Clay Liner Materials in Data Base (continued).

Site No.	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
82	4 1.5 x 10-8 0.29	Flexible-Wall 34 -	3 x 10-8	2.33	-	-	-	-	0.4	-
83	4 1.7 x 10-8 0.05	Flexible-Wall 34 -	4.5 x 10-8	2.33	-	-	-	-	0.4	-
84	-	-	1.3 x 10-7	2.33	-	-	-	-	0.8	-
85	-	-	2.8 x 10-8	2.33	-	-	-	-	0.8	-
86	2 2.2 x 10-8 -	Flexible-wall 14 -	1.5 x 10-8	2.25	-	-	-	-	-	-
87	2 2.6 x 10-8 -	Flexible-wall 14 -	1.4 x 10-8	2.25	-	-	-	-	-	-
88	2 3.9 x 10-8 -	Flexible-wall 14 -	2.3 x 10-8	2.25	-	-	-	-	-	-
89	2 3.1 x 10-8 -	Flexible-wall 14 -	2.1 x 10-8	2.25	-	-	-	-	-	-

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Table C-5. Material Properties for Soil-Bentonite Liners in Database.

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Percent Bentonite)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
1	Oxford, NJ 1991	Golder Assoc	- - -	- - -	- - -	- - -	- 3.75 -	-	-	
2	Southern Nebraska	D.L. Osadnick	31 51 -	31 36 -	32 13 -	32 32 -	- 9.0 -	15.0	17.1	SP
3	Southern Nebraska	D.L. Osadnick	31 51 -	31 36 -	32 13 -	32 32 -	- 9.0 -	15.0	17.1	SP
4	Southern Nebraska	D.L. Osadnick	31 51 -	31 36 -	32 13 -	32 32 -	- 9.0 -	15.0	17.1	SP
5	Southern Nebraska	D.L. Osadnick	31 51 -	31 36 -	32 13 -	32 32 -	- 9.0 -	15.0	17.1	SP
6	Kettleman City, CA 1987	Golder Assoc.	- - -	- 29 -	- - -	- 81 -	-	23.8	15.4	SP
7	Kettleman City, CA 1987	Golder Assoc.	- - -	- 29 -	- - -	- 81 -	-	23.8	15.4	SP
8	Borfer, TX 1988	McBride-Ratcliff	- 56 -	- 31 -	- - -	- 55 -	- 7.8	18.6	16.9	SP

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Table C-5. Material Properties for Soil-Bentonite Liners in Database (continued).

Site No.	Location and Date	Source of Data	LL (%)	PI (%)	Percent Gravel	Percent Fines	Percent Bentonite)	W _{opt} (%)	γ _{d,max} (kN/m ³)	Compactive Effort
9	Borfer, TX 1988	McBride-Ratcliff	- 65 -	- 39 -	- - -	- 63 -	10.5	20.1	16.5	SP
10	San Mateo County, Ca 1993	BFI	- 51 -	- 36 -	- 2 -	- 21 -	10.0	9.0	19.9	MP
11	Lead, South Dakota 1994	Golder Assoc.	- - -	- - -	- - -	- - -	- 14.7 -	17.7	16.8	SP
12	Mobile, AZ 1990	Golder Assoc.	- 60 -	- 38 -	- - -	- 39 -	4.0	13.5	18.5	SP

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Table C-6. Construction Information for Soil Bentonite Liners in Database.

Site No.	Compaction Criteria	Compactor	Compactor Mass (kg)	Passes per Lift	Lift Thickness (mm)	Number of Lifts	Pad Size (m x m or m ²)
1		Ingersol Rand S100	-	10	150	4	9 x 9
2	w > OWC, <+4 RC > 95% SP	CAT 815	20,000	6	150	6	31 x 11
3	w > OWC, <+4 RC > 95% SP	CAT 815	20,000	6	150	6	31 x 11
4	w > OWC, <+4 RC > 95% SP	CAT 815	20,000	4	150	6	31 x 11
5	w > OWC, <+4 RC > 95% SP	CAT 815	20,000	4	150	6	31 x 11
6	w > OWC RC > 90% MP	CAT 815	20,000	2	150	7	43 x 15
7	w > OWC +3 RC > 90% SP	CAT 815	20,000	2	150	7	43 x 15
8	w > OWC RC > 95% SP	CAT 815	12,600	6	150	6	13 x 28
9	w > OWC +2 RC > 92% SP	CAT 815	20,000	6	150	6	13 x 28
10	w > OWC+2, ,+5 RC > 90% MP	CAT 825	32,400	4	150	6	15 x 15
11	w > OWC, <+3 RC > 98% SP	-	-	-	150 - 230	3	11 x 11
12	w > OWC +2 RC > 95% SP	CAT 815 (1-4 lift), CAT CP433B (5 th lift), Sakai SV (6 th lift)	-	4	150	6	36 x 18

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Table C-7. Quality Control/Quality Assurance Data for Soil-Bentonite Liners in Database.

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
1	28 12.3 1.4	28 16.0 0.3	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
2	2 14.7 -	2 17.2 -	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
3	2 16.0 -	2 16.7 -	-	-	None	Verify $k \leq 1 \times 10^{-8}$ cm/s	
4	2 143 -	2 16.8 -	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
5	2 15.2 -	2 16.5 -	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
6	- 28.4 -	- 14.8 -	54	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
7	- 28.4 -	- 14.8 -	54	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
8	38 20.2 -	38 15.9 -	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
9	38 21.4 -	38 15.9 -	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	

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Table C-7. Quality Control/Quality Assurance Data for Soil-Bentonite Liners in Database (continued).

Site No.	w (%)	γ_d (kN/m ³)	P _o	ΔS_i	Distress	Purpose	Remarks
10	34 12.5 0.77	34 19.1 0.22	100	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
11	8 18.5 -	8 16.8 -	75	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	
12	32 15.5 -	32 17.9 -	-	-	None	Verify $k \leq 1 \times 10^{-7}$ cm/s	

Table C-8. Hydraulic Conductivity for Soil-Bentonite Liners in Database.

Site	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
1	4 5.5 x 10-8 -	D5084 - -	?	-						
2	2 3.0 x 10-8 -	D5084 34 -	3.0 x 10-8	2.33						
3	2 1.9 x 10-8 -	D5084 34 -	1.0 x 10-8	2.33						
4	2 6.0 x 10-8 -	D5084 34 -	3.0 x 10-8	2.33						
5	2 7.5 x 10-8 -	D5084 34 -	2.0 x 10-8	2.33						
6	7 6.9 x 10-9 -	- - -	1.6 x 10-8	2.33						
7	7 6.9 x 10-9 0.35	- - -	6.2 x 10-8	2.33						
8	- - -	- - -	2.2 x 10-8	2.33						

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Table C-8. Hydraulic Conductivity for Soil-Bentonite Liners in Database (continued).

Site	Thin-Wall Sampling Tube		SDRI		Lysimeter		TSB	30 cm Block	D _F /L	Ψ _o (kPa)
	k (cm/s)	Method, σ', i	k (cm/s)	Size (m ²)	k (cm/s)	Size (m ²)	k (cm/s)	k (cm/s)		
9	-	-	1.0 x 10 ⁻⁷	2.33						
	-	-								
	-	-								
10	10	-	3.0 x 10 ⁻⁸	2.33						
	2.6 x 10 ⁻⁸	-								
	-	-								
11	-	-	2.0 x 10 ⁻⁹	2.33						
	-	-								
	-	-								
12	6	-	2.0 x 10 ⁻⁸	2.33						
	3.2 x 10 ⁻⁸	-								
	-	-								

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